comma bacillus, and we would suggest to future observers that possibly acid media may be found better suited for the growth of this parasite. As to whether the micro-organism is frequently or constantly present in the contents of the intestine, our cultivations as above-mentioned are of no value. Nor does our examination of stained films enable us to speak definitely for or against the presence of this parasite. In the intestinal contents or the dejecta of cholera cases, we have seen appearances which resembled in many points the characters of the micro-organism in question; none of our films, however, show structures which are *unmistakeably* identical with those found by us in the substance of the mucous membrane.

We have only to add that not having cultivated this micro-organism artificially, we claim no right to say that it is the cause of Asiatic cholera. All we have to say is, that we have found it present in certain tissues of all the cholera cases which we had the opportunity of examining. Further investigation must decide whether or not it can be looked upon as the direct cause of the disease.

"An Instrument for the Speedy Volumetric Determination of Carbonic Acid." By WILLIAM MARCET, M.D., F.R.S. Received June 9. Read June 10. Revised by the Author June 29, 1886.

[PLATE 2.]

The principle of this instrument is the absorption of carbonic acid in a closed receiver by potassium hydrate, and the accurate measurement of the volume of dry atmospheric air required to re-establish the atmospheric pressure after complete absorption. The volume of air used for that purpose will exactly correspond to that of the carbonic acid gas absorbed. It is obvious that whatever be the reading of the barometer, the volume of air corresponding to that of the carbonic acid absorbed, will give the correct proportion of carbonic acid in the air submitted to analysis; but to obtain the weight of the gas present, and its proportion by weight, it will be necessary to reduce both the volumes of air analysed and of carbonic acid found to their volume at 0° (C.), and under a pressure of 760 mm. of mercury. Hence the necessity of recording the height of the barometer at the time of the experiment, or one reading may suffice for a number of determinations.

The instrument resembles two small gasometers, and consists of two tanks and two bell-jars, or air-holders, each of the latter being made to hold half a cubic foot of air. The bell-jars hang on a metallic cord which connects them with each other, and passes over two pulleys,

allowing the bell-jars to be moved up and down alternately in the tanks. The inside of the bell-jars communicates with the outside air by means of a U-shaped iron pipe, one limb of which opens inside the bell-jar above the fluid it contains, and the other outside on a somewhat lower level for sake of convenience. The tanks or troughs contain glycerine, over which floats a layer of almond oil an inch or two in thickness, and filling approximately the trough. The opening of the pipe above the surface of the oil enters loosely, so as to leave free passage of air, a neck in the bell-jar admitting a thermometer fitted air-tight through it. By this arrangement when the bell-jar is lowered, the thermometer descends into the inner limb of the U-pipe or stand-pipe without dipping into the oil or glycerine.

A measured volume of air to be analysed is drawn into one of the air-holders (selected for that purpose) by raising it to a certain height, and on lowering it slowly, after cutting off communication with the outside by a stop-cock, the air is driven first of all through an absorption apparatus and then into the second bell-jar, which has at that time an ascending motion. The whole apparatus is connected by brass tubes and stop-cocks, on one hand with a pressure-gauge, and on the other hand with a graduated glass receiver, immersed in mercury, and fixed to a bracket and rack movement by which it can be raised and lowered at will. The various parts of the instrument are all in air-tight communication with each other while the carbonic acid is being absorbed, so that the absorption will tell on the pressure-gauge, and by depressing the measured glass receiver into the mercury trough, and driving the air it contains into the air-holders, while keeping the eyes fixed on the pressure-gauge, it will be easy to restore the atmospheric pressure in the whole apparatus, and thus determine the volume of gas absorbed.

I shall now beg to describe in succession the various parts of this instrument, and next state how the analysis is made.

The Tanks.—One of the great difficulties I met with was the selection of the fluid to be used in the tanks. Water would not answer, first of all because it absorbed carbonic acid, and next on account of the tension of aqueous vapour. I tried a nearly saturated solution of common salt in water, so as to avoid any loss of carbonic acid by absorption, but after experimenting for a considerable time I had to reject the plan because of the vapour-tension, which I found impossible to take into account. I came to the conclusion that it was necessary to dry the air and submit it to analysis in the dry state, keeping it entirely out of reach of aqueous or other vapours. Bearing this in mind, glycerine appeared to me to be possessed of the required properties as a medium for confining the air in the bell-jars, and therefore for filling the tanks. It had the advantage of holding no water, but its thickness appeared at first sight a serious objection, as

from its adhesion to the sides of the bell-jars on their being raised, I thought there would be a difficulty in obtaining a fixed volume of air within them. However, glycerine was tried, and the objection found to be less than I had imagined, but glycerine absorbed water from the air, and in due time would give it out to the dry air submitted to analysis, so that glycerine could not be used without a protection from atmospheric moisture. It then occurred to me that some kind of oil might be made to float on the glycerine, thus completely isolating it from the external air, and almond oil—which does not thicken by exposure to the atmosphere—was adopted. The bath of glycerine covered with almond oil in which the bell-jars are now immersed was prepared in October last ; there is about one hundredweight of glycerine in each tank, and I tested the glycerine of one of the tanks for water four months and a half after it had been, it may be said, in daily use. This was effected by placing a weighed quantity of the glycerine for about half an hour under a bell-jar over sulphuric acid, and after that time it was found to have lost absolutely no weight. The layer of almond oil had, therefore, perfectly answered its object. The oil for confining the air to be analysed, ensured the absence of any vapour-tension, or any possible loss of gas from absorption, and, moreover, by lubricating the bell-jars prevented the glycerine from adhering to them, the oil itself, from its lightness, running rapidly down the sides of the receivers on their being raised or depressed. A simple experiment demonstrates the action of the oil. Let a glass tube opened at both ends be closed at one extremity with india-rubber tubing and a pinch-cock, and then glycerine be poured into the tube. By pressing on the tubing the glycerine is driven up, and on releasing the pressure it slowly subsides adhering to the glass; but if a little almond oil be poured over the glycerine, on compressing the tube the glycerine and oil are raised, but on releasing the pressure the glycerine runs down quickly to its former position without adhering to the glass.

The bell-jars or air-holders gave me no little trouble. They were made at first of thin sheet iron, but this, after much labour, was found inadequate, as the changes of temperature of the external air affected the gas through the metal, too rapidly to allow of a sufficiently fine correction. Every possible contrivance was adopted to overcome this difficulty. The tanks and bell-jars were enclosed in a wooden case with glazed doors opening sideways, and tinfoil shields were placed round the bell-jars so as to shelter them from any heat radiated from the outside, but these arrangements were too complicated and the shields had to be given up. I came to the conclusion that the only plan would be to keep the bell-jars under water during the whole of the analysis, and this was done by making use of jacketed bell-jars, the space inside the jackets being filled with water. A completely new instrument was then

constructed, the bell-jars being jacketed and the inside space of nearly half an inch in thickness was filled with water. Later on I substituted for water a solution of sodium sulphate saturated at a temperature exceeding that of my laboratory, so that the annular space in the bell-jars became filled with a crystallised solution of the salt. I thought by this plan to ensure a perfect stability of temperature in the air of the bell-jars during the analysis, any increase of temperature outside being transformed into motion through its action on the crystallised mass. The result was nearly as I had anticipated; still, after trying the plan for a considerable time, I finally gave it up and returned to the water-jacket which I now find quite satisfactory. There is a scale to each of the bell-jars, divided into four equal parts, and a pointer fixed to the rim of the tanks; by bringing the same line on the scale opposite the pointer before and after the analysis, the operator will be certain that the bell-jars hold exactly the same volume of air in both cases, admitting of course that the atmospheric pressure has been perfectly re-established.

The jacketed air-holders are raised and lowered by means of an iron weight worked over pulleys by a rack and drum movement, and handle; when the two bell-jars are at the same height, or level, they may be entirely released of the weights without their position being disturbed; but if one of the receivers, say the left-hand one, is to be depressed from that position and emptied of the air it contains, the left hand weight is brought to bear upon it, and by a slow movement of the handle that receiver is immersed entirely in the bath while the other one is raised as high as it will go. When thus raised it draws in common air; this air is filtered through marbles or fragments of pumice-stone, moistened with a solution of potassium hydrate, and then through calcium chloride, so that no carbonic acid nor moisture be admitted into the bell-jar. It is, of course, necessary to keep the taps communicating with the external air open in both tanks when the bell-jar is being emptied, or the oil will be drawn into one of the stand-pipes. Should such an accident occur, which never happens with a little practice, the oil will have to be let out from a small aperture closed with a screw tap in the lower bend of the U-pipe, while the thermometer has to be removed from the bell-jar, letting in air through the neck in which it fits. It is better to return an equal volume of glycerine to the tank rather than oil, from the difficulty the latter would have in finding its level in the tank. Should oil be added the bell-jar will have to be raised so far as it can go, and time allowed for the oil to assume its level below the rim of the receiver.

The cord which connects the bell-jars is liable to expand or contract, but this is remedied by turning a screw, placed so as to shorten or lengthen the cord, while the eye is kept on the pointers of both tanks

when they are made to point to the corresponding lines on the scale. Should the pointer of one bell-jar meet say the middle line on the scale, and the middle line on the scale of the other be above the corresponding pointer, that bell-jar will have to be depressed by working the screw until the middle line on its scale also corresponds with the pointer. This can be done without any trouble, and has seldom to be repeated the same day, while, at times, days elapse in succession without necessitating this correction.

The Absorption-tube.—Various descriptions of absorption-tube were tried before I obtained it in its present form. It has to fulfil two conditions, viz.: it must first of all absorb all the carbonic acid, secondly give out no water. My present arrangement, which works very well, is as follows: a straight hollow cylinder, 2 feet 3 inches in height, made of thin sheet copper and silvered inside, is jacketed and surrounded with glycerine over which floats a thin layer of oil to prevent the absorption of water. The cylinder is filled with fragments of pumice-stone in the midst of which is inserted a long metallic tube. The cylinder is closed with an india-rubber cork, perforated, through which is inserted a glass T-piece inverted. A very delicate thermometer divided into tenths of a degree Fahrenheit is run through the upper tube of the T-piece into which it fits air-tight, while the horizontal limb is placed in communication with the left-hand bell-jar by means of india-rubber tubing. The thermometer has a very long stem, and its bulb reaches far down into the metallic tube in the midst of the pumice-stone, thus registering the temperature of the air in the absorption-tube. The space left between the fragments of pumice-stone measures 1600 c.c. A narrow U-shaped glass tube connects the copper cylinder with another wider vertical glass tube, the latter being filled with pieces of caustic potash, and into it a narrow glass tube is fitted air-tight with an india-rubber stopper; the latter is jacketed, the annular space being filled with water. Thus the heat formed by the combination of the carbonic acid with the alkali distributes itself throughout the absorption-tube, and is prevented from reaching the right-hand bell-jar by the water in the jacket which absorbs it on its way. The U-shaped tube connecting the vertical portions of the absorption apparatus has a tube soldered to its lower part and widened into a bulb, an arrangement the object of which is to drain out the alkaline fluid after it has done flowing over the fragments of pumice-stone; the tube beyond the bulb is finally closed with india-rubber tubing and a pinch-cock.

The alkaline fluid for the absorption of the carbonic acid consists of half its volume of a saturated aqueous solution of potassium hydrate, and half its volume of pure glycerine, and the mixture is made to dissolve as much caustic potash in sticks as it will take up. An excess of the alkali is invariably left in the fluid, so that

should any water accidentally reach the solution it will always remain saturated. This solution answered its requirements in every way. The thickness of the glycerine enabled it to adhere to the fragments of pumice-stone in the form of a thick layer, while the water of the potassic solution was so firmly retained that none was given out to the current of air passing through it. Placed over sulphuric acid under a receiver a sample of this mixture underwent no loss of weight. This fluid absorbs carbonic acid with the greatest speed, and I am not yet able to say when its power becomes exhausted. It is held in bottles kept near the absorption-tubes, and before each analysis about 200 c.c of the solution is poured into the copper cylinder, when it trickles down the pumice-stone appearing shortly afterwards in the exit tube, when it is let out into the bottle. The bulb blown on the exit tube is indispensable as a means of collecting the solution which remains behind and would otherwise stop the communication between the bell-jars—an accident which frequently happened until the present arrangement was adopted. The air after leaving the absorption apparatus just described passes over pieces of caustic potash, where it deposits any last traces of carbonic acid which may have escaped from the absorbing fluid; it is finally cooled by the water-jacket, and in this state is collected in the right-hand bell-jar.

The heat produced by the combination of the carbonic acid with the alkali introduced, was at first a serious difficulty in the working of my instrument. Various means were tried either to get rid of it or estimate its influence so as to correct it by calculation. At last I succeeded—I may say beyond my expectations—in doing away entirely with this difficulty. The means I employed was surrounding the absorption-tube with the non-conducting material glycerine, and determining the temperature of the air in this tube with a very delicate thermometer.

The measuring apparatus consists of a graduated receiver, holding about 800 c.c., and moving up and down over mercury contained in a strong glass trough. The receiver is drawn out at the top into a long tubular neck, and this is fixed by a bracket to a rack and pinion movement. The opening in the neck is connected by india-rubber tubing and a combination of T-pieces, with a gauge on one hand and the bell-jars on the other, while a small tube of calcium chloride is interposed in such a way as to dry the atmospheric air as it is drawn into the graduated glass receiver.

The gauge is a very pretty instrument, which was made for me at the works for the construction of physical instruments at Geneva. It consists of a glass U-tube which can be raised or depressed by a rack and pinion movement, and a web stretched across the tube, though fixed to an independent brass-piece. By this simple arrangement it is

easy to ascertain when the gauge is exactly under atmospheric pressure. The fluid I have selected for the gauge is coloured petroleum, on which the slightest difference of pressure will tell.

Finally, there is an arrangement of brass tubes and stopcocks through which the air, after having been driven from the left-hand bell-jar into the other through the absorption-tube, can be transferred from the right to the left bell-jar without retracing its passage through the absorption apparatus.

In my early experiments, india-rubber tubing, pinch-cocks, and glass T-pieces were used, but I substituted for these the present brass tubes and stopcocks, and the air-tightness of all the apparatus can be thoroughly relied upon. It is not possible to do away entirely with india-rubber tubes, but those in use are now varnished with several coats of copal varnish, and made thereby perfectly air-tight.

The Analysis.—The air to be analysed, which, so far has been air expired from the lungs or such air mixed with common air, is first of all collected in an india-rubber bag, faced on both sides with oil-silk in order to prevent any loss of carbonic acid by diffusion through its substance. The bag is next connected by india-rubber tubing with a gas-holder or counterpoised bell-jar, working in and out of a bath of glycerine covered with a layer of almond oil. By weighting the counterpoise of the bell-jar, the latter is slowly raised, aspiring the air from the bag. A scale on the bell-jar and a pointer on the rim of the tank enable the volume of air to be read off, but of course the extra weight used for giving the receiver its ascending motion will have to be removed and the holder placed under atmospheric pressure previous to taking the observation. I now find it more convenient to read off the volume of air to be analysed from a smaller bell-jar holding 11 litres of air. After collecting the air from the bag into the larger receiver, which, when full, contains about 42 litres, it is driven into the smaller bell-jar through a glass desiccator full of calcium chloride, where it leaves its moisture without losing any of its carbonic acid. In order to dry the gas thoroughly, it should pass through the desiccator at the rate of no more than a litre per minute.

The next step will be to bring this air in the small holder exactly under atmospheric pressure, and a special contrivance had to be adopted to effect this object. The instrument used is a clamp and a screw in connexion with each other; the screw, by means of a crank movement, raises or depresses the clamp, while the fulcrum is the rim of the tank to which this instrument is fixed. The cord holding the counterpoise passes through the open jaws of the clamp, and is free to move up and down; but when the air in the receiver has to be brought under atmospheric pressure, by turning a nut the clamp is closed and the cord fixed: then, on moving the screw with another nut either to one side or the other, the bell-jar is raised or

depressed. The adjustment is exceedingly fine, and by testing the pressure of the air in the holder with a gauge supplied with coloured petroleum, the air in the bell-jar can be brought under atmospheric pressure with the greatest degree of accuracy. I am indebted to Mr. W. Parkinson, Engineer, for the mechanism of this delicate adjusting movement.

The (smaller) air-holder is now connected with the left-hand bell-jar of the analysing apparatus by varnished india-rubber tubing, in the track of which is another tube of calcium chloride (omitted in the plate), care having been taken to rinse out previously this connecting tube with the air to be analysed. The bell-jar is now raised by turning the handle of the drum and lifting slowly the iron weight which keeps the receiver immersed in the tank. When filled, the air is brought under atmospheric pressure by the adjusting apparatus, and a minute or two are allowed to elapse to make sure that the pressure is constant; the volume of air to be analysed is then read off on the scale of the air-holder.

The temperature indicated by the thermometers in the two bell-jars is observed by means of two little telescopes fitted into the glazed shutters of the case, and which magnify considerably the divisions of the instruments. By this means the temperature in the bell-jars can be estimated to the fiftieth of a degree Fahrenheit, and are recorded when steady; the temperature in the absorption-tube is also noted. After opening and closing the requisite stopcocks, the air is driven slowly by means of the drum-handle through the absorbing apparatus into the right-hand bell-jar, which is simultaneously raised. I find from experience that about 7 litres are sufficient, and indeed the most convenient for the analysis of air expired from the lungs; and four minutes suffice for the absorption of the whole of the carbonic acid of that air run over the alkaline solution. After the first operation, it is obvious that the air filling the pipes of the left-hand bell-jar has been left behind. By means of a combination of tubes and taps, the two bell-jars are now brought into immediate communication, and the air is returned into the left bell-jar up to the original mark on the scale without passing through the absorption-tubes. Meanwhile, a considerable suction has taken place in the apparatus from the absorption of the carbonic acid, and this is shown by the pressure-gauge. The small graduated glass receiver, originally full of common air under atmospheric pressure, and which stood at 0, is depressed into the mercury, and by this means atmospheric pressure is readily re-established in the whole apparatus, as seen by the petroleum in the gauge returning to exactly the same level in the two limbs; the carbonic acid normally present in this atmospheric air is not taken into account as too small in its proportion to affect the correctness of the

result. It may be advisable to drive the air into the apparatus by degrees as the absorption takes place, and this is my ordinary mode of procedure. In order to ensure the absorption of the whole of the carbonic acid, leaving behind but an insignificant fraction, the air should be passed at least three times through the absorption-tube, or, in other words, should be made to circulate three times through the apparatus before recording the total amount of carbonic acid present. The small fraction of carbonic acid left would of course become increased after each analysis if allowed to remain in the instrument. It may therefore be advisable to run the air in the left-hand bell-jar through the absorption-tube before commencing an analysis. After the air has circulated three times through the absorption-tube the steadiness of the reading for the volume of carbonic acid absorbed, should the air be passed again and again through the absorption-tube, is usually remarkable, unless there should be an alteration in the temperature of the apparatus, when the reading is observed to follow the changes of temperature. The volume of air introduced into the apparatus to fill up the vacuum is now read off, as also the temperatures of the two bell-jars and absorption-tube. All this is done without drawing the shutters of the case containing the bell-jars, two little windows admitting the hands to work the taps; the absorption apparatus is outside the case at the back (although shown in the plate as inside the case). An instrument which has necessitated such a long description will be thought slow and tedious in its working, but such is far from being the case, considering that the actual analysis will take from 20 minutes to half-an-hour. I expect, however, an increase of speed by substituting a mechanical movement for the hand to turn the handle. Time can probably also be saved by passing the air to be analysed through a tube immersed in water at the temperatre of the bell-jars. When the temperatures and pressures become rapidly steady, the time required for the analysis is of course shortened.

I have not yet found out the shortest period required for depressing or raising the bell-jars; if the movement is too rapid a displacement takes place in the level of the oil in the tanks, and a slight suction follows which of course will be mistaken for so much carbonic acid, a slow movement given to the bell-jars overcomes that objection completely.

No additional time is taken up for running the alkaline solution through the absorption-tube, as this is done by another person while the observer is filling and adjusting. Of course it is only after acquiring some experience that the above speed is obtained.

Compared with Pettenkofer's method, the present instrument claims much greater speed, for while by the former process the solution holding the barium carbonate has to be left a day or over night for the

subsidence of the precipitate, with my instrument the analysis can be made at once, and in a short time. It might be objected that Pettenkofer's method could be carried out as far as the combination of the carbonic acid with the barium, the fluid being preserved for analysis in well-stoppered bottles. A number of determinations in succession might thus be obtained partially made, the final analysis being put off to a future period. I had to adopt this very plan myself in my experiments on the influence of altitude on the chemical changes of respiration, but found it inconvenient in many ways and sometimes objectionable. I am now alluding to air containing over 1 per cent. of carbonic acid; so far my experience does not extend to atmospheric air. I hope soon, however, to be able to determine carbonic acid in the atmosphere by the same means, as I have had a much larger instrument made for that purpose, each bell-jar holding 3 cubic feet of air.

In order to test the accuracy of my instrument, it was necessary to compare analyses of the same air by this means and by another reliable method, and for that purpose I selected that of Pettenkofer which was carried out with one of the cylinders I have formerly described in the "Journal of the Chemical Society," 1880.

The following are eighteen of the comparative analyses made by the two methods:—

Carbonic Acid in 100 *parts of Air analysed.*

First Analysis.

1st—Volumetric method	4·694
2nd „ „	4·633
Mean	4·663
By Pettenkofer's method	4·642
Difference	0·021=0·45 per cent.

Second Analysis.

Volumetric method	4·560
By Pettenkofer's method	4·580
Difference	0·020=0·4 per cent.

Third Analysis.

Volumetric method	4·495
By Pettenkofer's method	4·435
Difference	1·060=1·3 per cent.

Fourth Analysis.

1st—Volumetric method	3·630
2nd „ „	3·670
Mean	3·650
By Pettenkofer's method	3·613
Difference.....	0·037=1·0 per cent.

Fifth Analysis.

1st—Volumetric method	4·478
2nd „ „	4·486
Mean	4·482
By Pettenkofer's method	4·516
Difference.....	0·034=0·75 per cent.

Sixth Analysis.

1st—Volumetric method	4·883
2nd „ „	4·930
Mean	4·906
By Pettenkofer's method.....	4·891
Difference.....	0·015=0·3 per cent.

Seventh Analysis.

1st—Volumetric method	3·230
2nd „ „	3·210
3rd „ „	3·217
Mean	3·219
By Pettenkofer's method.....	3·209
Difference.....	0·010=0·3 per cent.

Eighth Analysis.

Volumetric method.....	3·266
By Pettenkofer's method.....	3·271
Difference.....	0·005=0·15 per cent.

Ninth Analysis.

		Difference from means.
1st—Volumetric method	2·780	0·4 per cent.
2nd „ „	2·768	0·08 „
3rd „ „	2·762	0·3 „
Mean	2·770	
By Pettenkofer's method	2·774	
Difference	0·004=0·15 per cent.	

Tenth Analysis.

		Difference from means.
1st—Volumetric method	4·093	0·07 per cent.
2nd „ „	4·089	0·05 „
3rd „ „	4·088	0·05 „
Mean	4·090	
By Pettenkofer's method	4·044	
Difference	0·046=0·9 per cent.	

Eleventh Analysis.

		Difference from means.
1st—Volumetric method	3·563	0·4 per cent.
2nd „ „	3·560	0·4 „
Mean	3·561	
By Pettenkofer's method	3·575	
Difference.....	0·014=0·4 per cent.	

Twelfth Analysis.

Volumetric method	4·339
By Pettenkofer's method	4·305
Difference.....	0·034=0·8 per cent.

Thirteenth Analysis.

1st—Volumetric method	2·026
2nd „ „	2·022
Mean	2·024
By Pettenkofer's method.....	2·024
Difference.....	0·000=0·0 per cent.

Fourteenth Analysis.

Volumetric method	2·516
By Pettenkofer's method	2·508
Difference	0·008=0·3 per cent.

Fifteenth Analysis.

1st—Volumetric method	2·808
2nd „ „	2·783
Mean	2·795
By Pettenkofer's method	2·788
Difference	0·007=0·25 per cent.

Sixteenth Analysis.

1st—Volumetric method	2·935
2nd „ „	2·939
Mean	2·937
By Pettenkofer's method	2·939
Difference	0·002=0·077 per cent.

Seventeenth Analysis.

Volumetric method	4·392
By Pettenkofer's method	4·390
Difference	0·002=0·04 per cent.

Eighteenth Analysis.

1st—Volumetric method	0·9327
2nd „ „	0·9412
Mean	0·9369
By Pettenkofer's method	0·9327
Difference	0·0042=0·43 per cent.

These eighteen series of analyses illustrate the results to be obtained by the use of my instrument.

The temperatures of the bell-jars are easily read to a fraction of the tenth of a degree Fahr., and the three corrections for temperature take no time to make. By waiting till the temperatures in the bell-jars,

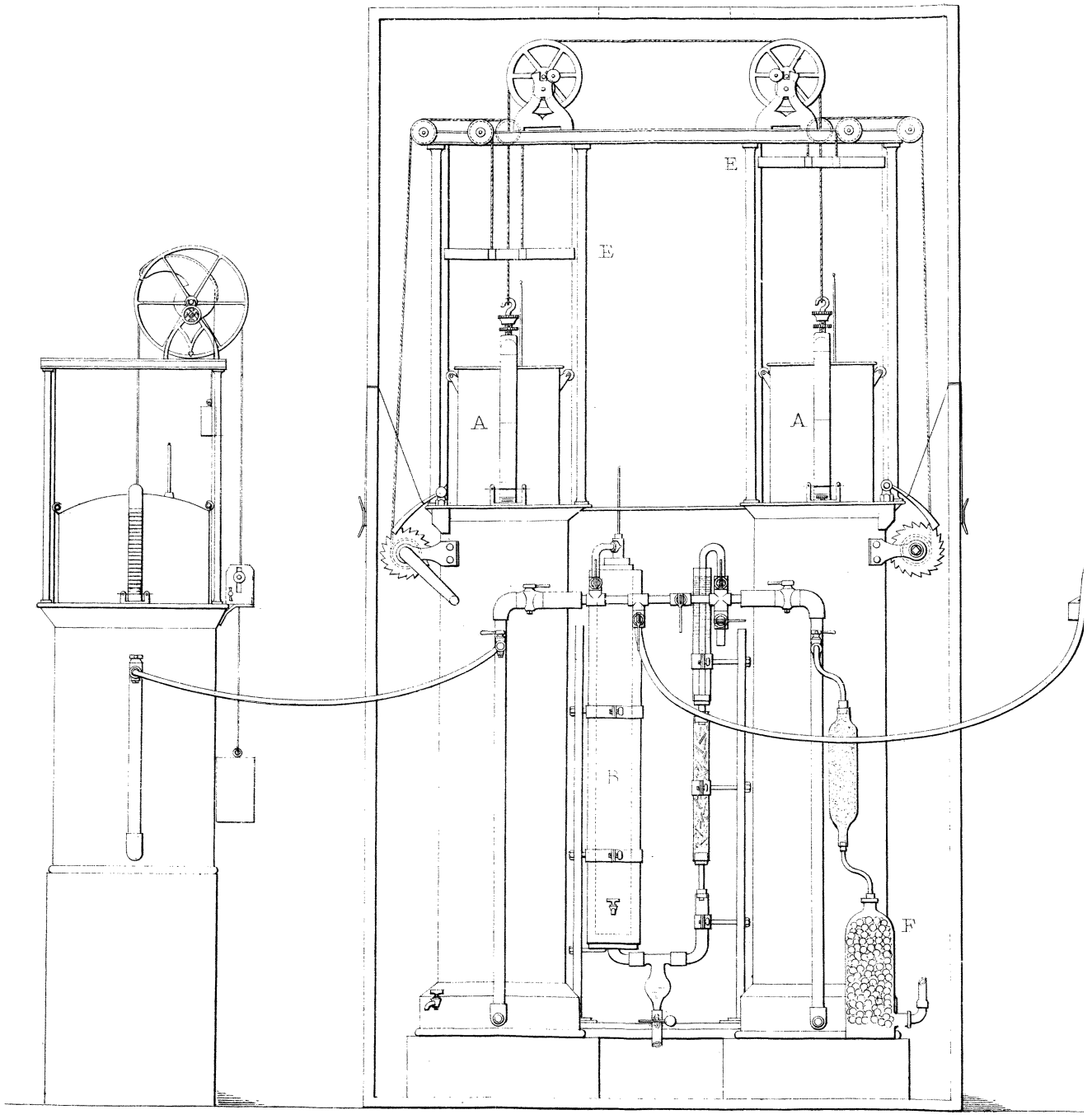
after the absorption of carbonic acid, have risen to their original readings, or very nearly so, the correction to be applied is all but limited to the change of temperature in the 1600 c.c. of the absorption-tube, and is hardly likely to exceed 4 or 5 c.c.

The petroleum gauge is most interesting to watch; when the absorption is complete, after the air has circulated three times through the absorption-tube, the reading of the graduated bell-jar (absolutely under atmospheric pressure) is extremely steady. It remains so for a minute or two, during which time the thermometers rise in both bell-jars; this is owing to the circumstance that the glycerine in the tanks is nearly always slightly colder than the water in the jacket of the bell-jars, and the air on its way through the stand-pipe immersed in the glycerine becomes a trifle colder. As the temperature in the bell-jars approaches its original reading, the pressure from the expansion of the air they contain begins to assert itself, and in order to keep the air under atmospheric pressure the graduated bell-jar must be gently raised. When the thermometers have reached their original height in the jacketed bell-jars of the instrument, the atmospheric pressure again remains exceedingly steady, and there is no difficulty in reading the result. It sometimes happens that after a time, especially in hot weather, the temperature slowly rises by two or three tenths of a degree or more beyond its original reading. In such a case the working of the instrument is so perfect that by introducing the correction required for this increased temperature in the proportion of 1 : 492 of the volume of air analysed per 1° F., the result obtained is the same as it was on the occasion of the first reading.

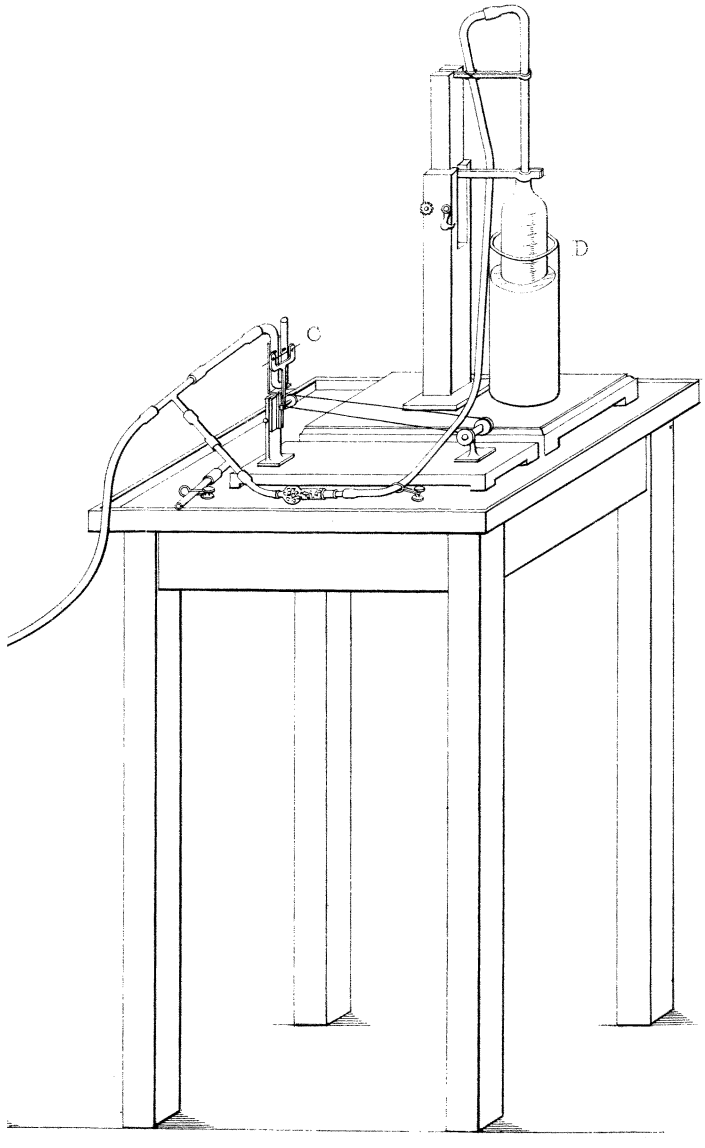
It is important to consider how far the instrument is reliable. At first I had much difficulty in obtaining in every analysis the same results by the new volumetric and Pettenkofer's methods; at last I found that the only cause of error left was the displacement of the surface of the oil, occasioned by working the bell-jars too fast; when moved slowly, the results by both methods invariably agreed. I conclude that air containing about 4 per cent. of carbonic acid will yield within 0·5 per cent. of the proportion which would be obtained by Pettenkofer's method, and air containing 1 per cent. of carbonic acid will give a result within 1 per cent. of that to be obtained by Pettenkofer's. In the last analysis I have quoted, air containing less than 1 per cent., or 0·9327 per cent. only of carbonic acid, gave with the two methods a difference of 0·45 per cent., a very satisfactory result.

In conclusion I must beg to return my best thanks to Professor Schäfer for having kindly allowed me the exclusive use of a room in the Physiological Department of University College where these researches were carried out; to Mr. W. Parkinson, of the firm of Messrs. William Parkinson and Co., gas engineers, who constructed

Marcet.



A. A. *Jacketed Air Holders.*
B. *Absorption Apparatus.*
C. *Gauge.*
D. *Graduated Receiver.*
E. E. *Iron Weight.*
F. *Marbles mois*



West Newman & Co. imp.

ι Weights.

bles moistened with Potassium Hydrate.

the whole of these instruments for me, and to whom I am indebted for some valuable suggestions; and finally to Mr. Landriset, of Geneva, my assistant since last January, whose care and perseverance, especially with reference to the determinations by Pettenkofer's method, have added not a little to the success of the inquiry.

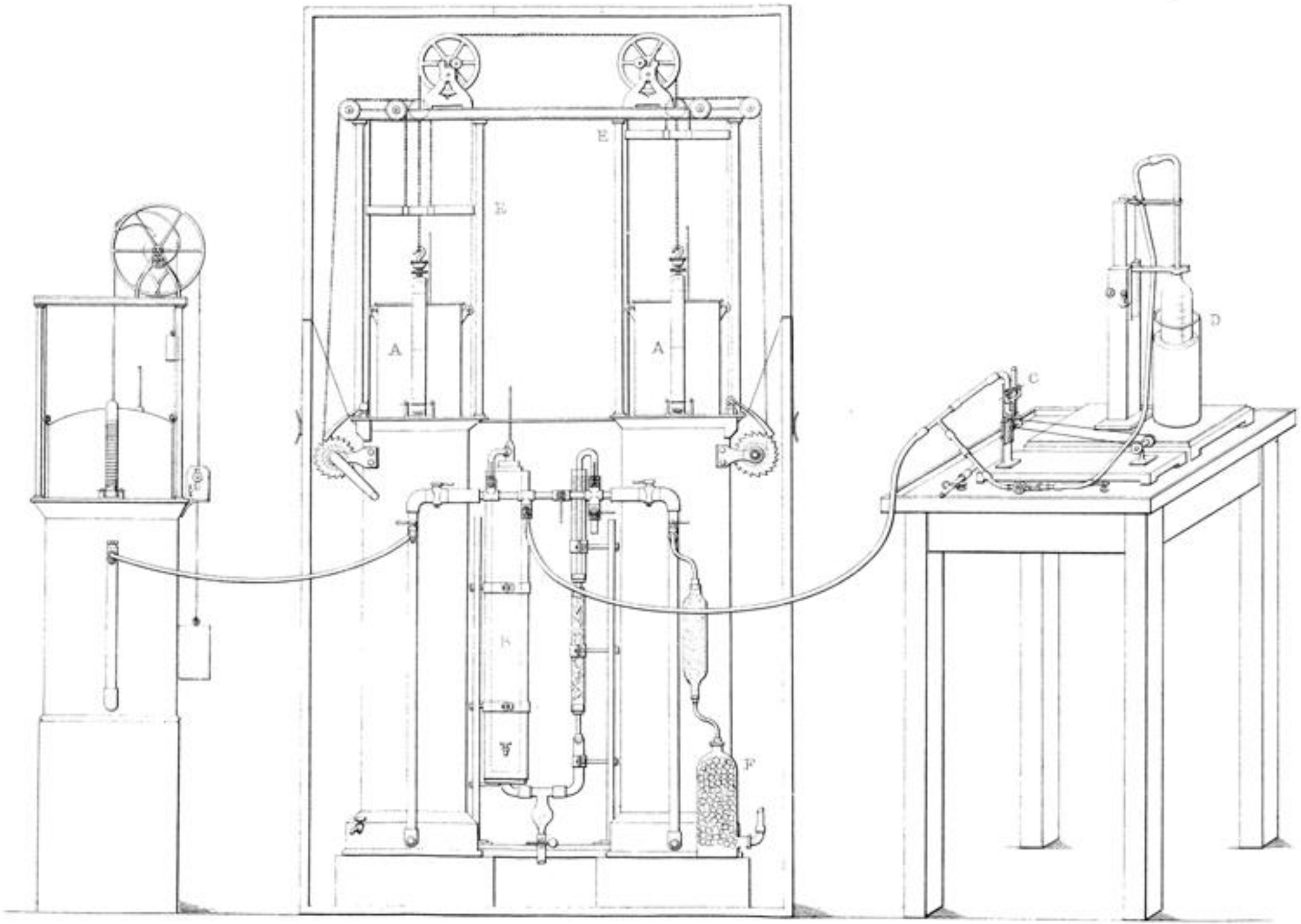
The drawing of the instrument which accompanies this paper (Plate 2) needs no explanation beyond the few notes referring to letters at the foot of the plate.

"Researches in Stellar Photography. 1. In its relation to the Photometry of the Stars; 2. Its applicability to Astronomical Measurements of great Precision." By C. PRITCHARD, Savilian Professor of Astronomy in Oxford. Received May 20. Read May 27, 1886.

Several attempts have already been made to connect the photographic images of stars with their photometric magnitudes, and consequently with their relative brightness; but hitherto, so far as I know, this relation has been sought by comparing the *impressions* made on the eye rather than as resulting from rigorous measures. With a view to the removal of this indefiniteness, unscientific unless it be unavoidable, I have undertaken a series of instrumental measures of the diameters of the photographic images impressed on sensitised films, which has led to the establishment of a remarkable physical relation (mathematically expressed) between the diameters of the stellar images and their photometric magnitudes, as determined by instrumental means: a method which seems to me to be free from systematic error and personal bias.

With this end chiefly in view, though accompanied also with the hope of obtaining still further, and perhaps even more valuable application of the photographic method to astronomical observations, I procured a number of gelatine dry plates, each being about 2 inches square. The comparative smallness of these plates was determined or suggested by my desire to obtain pictures of such small parts only of the sky as would fall within the ascertained limits of astronomical accuracy of the telescopic field of view, *i.e.*, a field possessing no measurable distortion, and consequently restricted to about a square degree. These plates were exposed in the focus of the well-known De La Rue reflecting telescope, of 13 inches aperture, erected in the University Observatory, at Oxford.

Several plates of the Pleiades were taken with varying times of exposure, and on these were impressed images of portions of the group, extending to stars of approximately the tenth magnitude. The



A . A . *Jacketed Air Holders.*
B . *Absorption Apparatus.*
C . *Gauge.*
D . *Graduated Receiver.*
E . E . *Iron Weights.*
F . *Marbles moistened with Potassium Hydrate.*